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NATIONAL DAM SAFETY PROGRAM. LAKE OF THE HILLS DAM (MO 30877), --ETC(U)
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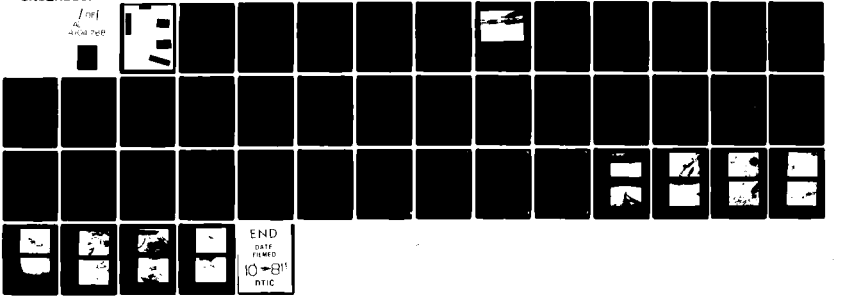

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This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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LAKE OF THE HILLS DAM
BOLLINGER COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30077

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

PREPARED BY: ST. LOUIS DISTRICT CORPS OF ENGINEERS
FOR: GOVERNOR OF MISSOURI

AUGUST 1979

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Lake of the Hills Dam
State Located	Missouri
County Located	Bollinger County
Stream	Cane Creek
Date of Inspection	23 May 1979

Lake of the Hills Dam was inspected by an interdisciplinary team of engineers from the Memphis District, U. S. Army Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and State agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as a small size dam with a high downstream hazard potential. Failure would threaten the life and property of 2 or more families downstream of the dam.

The inspection and evaluation indicate that the spillway does not meet the criteria set forth in the guidelines for a dam having the above mentioned size and classification and hazard potential. For its size and hazard category, this dam is required by the guidelines to pass from one-half PMF to PMF. However, considering the high-hazard potential to life and property of two families downstream of the dam, the PMF is considered the appropriate spillway design flood. The PMF is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The emergency spillway will only pass 30 percent of the PMF before the dam embankment is overtopped. Because the spillway will not pass one-half of the PMF without overtopping but will pass the 10-year frequency flood, the dam is classified as "unsafe non-emergency." Also the spillway will pass the 100-year flood without overtopping which is a flood that has a 1 percent chance of being exceeded in any given year. There were no other hydrologic or hydraulic deficiencies.

Other deficiencies visually observed by the inspection team were trees, bushes, and seepage on the downstream embankment slope and toe; erosion gullies and sloughing on the downstream embankment slope; minor wavewash on the upstream embankment slope; and undermining of the downstream ends of the primary and emergency discharge structures. Another deficiency found was the lack of seepage and stability analysis records.

It is recommended that the owner take action to correct or control the deficiencies described. Corrective works should be in accordance with analyses and design performed by an engineer experienced in the design and construction of dams.

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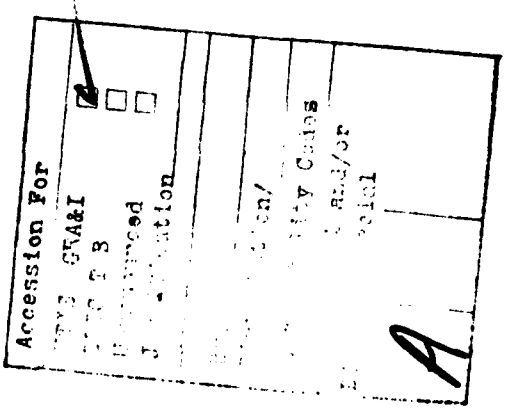
Chief, Engineering Division
19 SEP 1979
Date

APPROVED BY: SIGNED
Colonel, CE, District Engineer
19 SEP 1979
Date



Overview of Lake and Dam

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
LAKE OF THE HILLS DAM - ID NO. 30077

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SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the District Engineer for the St. Louis District, Corps of Engineers, directed that a safety inspection of the Lake of the Hills Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many State agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure built in a narrow valley in the uplands which border the Mississippi Embayment. Topography adjacent to the valley is rolling to steep. Soils in the area are formed of red silty clays with fragments of dolomite and chert. Topography in the vicinity of the dam is shown on Plate 2.

(2) A vertical drop inlet constructed of 8.3 feet of 36-inch diameter corrugated metal pipe (CMP) junctioned with 105 feet of 36-inch diameter CMP running horizontally through the embankment serves as the primary discharge. An emergency spillway which is located in the left abutment is a rectangular concrete channel with an average bottom width of 14 feet. The top elevation of the vertical drop inlet and the low point of the emergency spillway is 535.1 feet m.s.l. which will cause both of these structures to begin discharging at the same elevation. The sliding gate located at the bend of the vertical drop inlet can be used to draw down the lake approximately 9 feet. Using this procedure, some flood storage can be developed.

(3) Pertinent physical data are given in paragraph 1.3 below.

b. Location. The dam is located in the south central portion of Bollinger County, Missouri, as shown on Plate 1. The lake formed by the dam as shown on Plate 2 is located on the Marquand, Missouri Quadrangle sheet in Section 23, Township 30 North, Range 9 East.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1 c above. Based on these criteria, this dam and impoundment is in the small size category.

d. Hazard Classification. Guidelines for determining hazard classification are presented in the same guidelines as referenced in paragrapa c above. Based on referenced guidelines, this dam is in the High Hazard Classification.

e. Ownership. This dam is owned by a group of people represented by Sheriff Eddie Graham of Marble Hill, Missouri 63764.

f. Purpose of Dam. The dam forms a 65-acre recreational lake.

g. Design and Construction History. The dam was designed by the Missouri Department of Conservation and constructed by the J.R. Hahs Construction Company in 1960. Personnel from the Missouri Department of Conservation reportedly inspected the construction operations. There are no design plans available as the original plans were discarded five years after construction. Borrow material for construction of the dam was taken from the area near the right abutment. The embankment material is believed to consist predominantly of the native red silty clays with dolomite and chert fragments intermixed. The effort utilized in compacting the borrow material is unknown. The dam reportedly has a core trench 10 feet wide that extends 6 to 8 feet down to red clay. The embankment was reportedly to have been constructed with a 20 foot crown width and upstream and downstream slopes of 1V on 3H and 1V on 2H respectively. Based on the inspection survey the average upstream and downstream embankment slopes are 1V on 2.9 H and 1V on 2.25H respectively. It is unknown whether or not slope stability and seepage analyses using suitable loading conditions were performed.

h. Normal Operating Procedure. Normal rainfall, runoff, transpiration, and evaporation all combine to maintain a relatively stable water surface elevation. A screw-type sliding gate located at the bend of the drop inlet is capable of drawing down the water level approximately 9 feet for biological maintenance of the lake.

1.3 PERTINENT DATA

a. Drainage Area.- 492 acres (Topographic Quadrangle)

b. Discharge at Damsite.

(1) Discharge can take place through a vertical drop inlet and a rectangular concrete emergency spillway.

(2) Estimated experienced maximum flood at the damsite--unknown.

c. Elevation (Feet above M.S.L.).

(1) Observed Pool - 535.1

(2) Normal Pool - 535.1

(3) Spillway Crest - 535.1

(4) Maximum Experienced Pool - Unknown

(5) Top of Dam - Maximum - 539.8
Minimum - 538.7

(6) Maximum Pool (PMF) - 540.5

(7) Invert of Discharge Pipe - 524.5

(8) Streambed at centerline of dam - 501± (Extrapolation from survey).

(9) Maximum Tailwater - Unknown.

d. Reservoir. Length of maximum pool - 3300± feet

e. Storage (Acre - feet).

(1) Observed Pool - 899

(2) Normal Pool - 899

(3) Spillway crest - 899

(4) Maximum Experienced Pool - Unknown

(5) Top of Dam - Maximum - 1225
Minimum - 1143

(6) Maximum Pool (PMF) - 1274

f. Reservoir Surface Area (Acres).

(1) Observed Pool - 64.90

(2) Normal Pool - 64.90

(3) Spillway Crest - 64.90

(4) Maximum Experienced Pool - Unknown

(5) Top of Dam - Maximum - 75.52
Minimum - 73.03

(6) Maximum Pool (PMF) - 76.84

g. Dam.

(1) Type - earth embankment

(2) Length - 750± feet

(3) Height - 37 feet maximum

(4) Top width - 20± feet

(5) Side Slopes -

(a) Downstream - 1V on 2.25 H (Average from survey section)

(b) Upstream - 1V on 2.9 H (Average from survey section)

(6) Zoning - Unknown

(7) Impervious core - Unknown

(8) Cutoff - reportedly has a core trench 10 feet wide extending 6 to 8 feet down to red clay.

(9) Grout curtain - Unknown

h. Diversion and Regulating Tunnel. None

i. Primary Discharge System.

(1) Type - An uncontrolled 36-inch diameter CMP drop inlet junctioned with a 36-inch diameter discharge pipe (see Paragraph 1.2 a).

(2) Length of 36-inch diameter drop inlet pipe - 8.3 feet

(3) Length of 36-inch diameter horizontal pipe - 105 feet

(4) Top elevation of vertical pipe - 535.1 feet m.s.l.

(5) Invert of discharge pipe - 524.5 feet m.s.l.

j. Emergency Spillway.

(1) Type - Uncontrolled rectangular concrete

(2) Width of weir - 14 feet (bottom width)

(3) Length of weir - Approximately 80 feet from center line of spillway.

(4) Crest elevation - 535.1 feet m.s.l.

k. Regulating Outlet. Screw-type sliding gate located at bend of drop inlet used to drawdown the lake to control weed and moss growth.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

The dam was designed by the Missouri Department of Conservation. There are no design plans available as the original plans were discarded five years after construction of the dam. Whether or not slope stability and seepage analyses were performed using suitable loading conditions is unknown.

2.2 CONSTRUCTION

The dam was constructed by the J.R. Hahs Construction Company in 1960. Personnel from the Department of Conservation reportedly inspected the construction operations. Borrow material for construction of the dam was taken from the area near the right abutment. The embankment material is believed to consist predominantly of the native red silty clays with dolomite and chert fragments intermixed. The effort utilized in compacting the borrow material is unknown. The dam reportedly has a core trench 10 feet wide that extends 6 to 8 feet down to red clay. The embankment was reportedly to have been constructed with a 20 foot crown width and upstream and downstream slopes of 1V on 3H and 1V on 2H respectively. Based on the inspection survey the average upstream and downstream embankment slopes are 1V on 2.9 H and 1V on 2.25 H respectively.

2.3 OPERATION

A screw-type sliding gate located at the bend of the drop inlet is utilized for drawing down the lake level to control weed and moss growth. The emergency spillway has been used but the maximum depth of flow is unknown.

2.4 EVALUATION

a. Availability. The only engineering data readily available are the personal recollections of the owners and the recollections of Missouri Department of Conservation personnel.

b. Adequacy. The field and visual inspections presented herein are considered adequate to support the conclusions of this report. There were no design data available to evaluate the adequacy of the hydrologic or hydraulic design. Also, seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Validity. Not applicable.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. Visual inspection of the Lake of the Hills Dam was performed on 23 May 1979. Personnel making the inspection were employees of the Memphis District, Corps of Engineers, and included a geologist, hydraulic engineer, and soils engineer. The owners of the dam were represented by Sheriff Eddie Graham who accompanied the inspection team. Specific observations are discussed below.

b. Project Geology. The area in the vicinity of the dam is located on the Salem Plateau of the Ozark Plateau Province. The Ozark Plateau is part of the interior highlands of the United States. The province is a reflection of the Ozark Dome with dips to the east of 70-80 feet per mile with a gentler slope to the west of 10-20 feet per mile. The drainage pattern in the area is dendritic. Common features of the area are relatively flat hill tops between the stream valleys which enable the area to resemble a dissected peneplain.

The dam is located on the extreme edge of the Salem Plateau. The terrain in the area is gently rolling with flat slopes around the perimeter of the lake. Although the dam is located in the proximity of a Seismic Risk Zone 3 there is little possibility of a landslide into the lake in the event of an earthquake.

Based on a visual inspection of the dam it is composed of material borrowed from the immediate vicinity and probably consists of a sandy red clay with angular stone fragments.

A light grey dolomite interbedded with a tan sandstone is exposed in the channel leading from the spillway. The dolomite is friable and badly weathered at the surface. The sandstone is loosely cemented. No other exposed rock faces were observed in the vicinity of the dam. Based on the relative elevation of the rock it is likely that it underlies the dam but is covered with alluvial material. The rock is the Roubidoux Formation of the Lower Ordovician.

c. Dam. No detrimental settlement, cracking, or animal burrows were observed in or near the earth embankment. Typical existing cross-sections of the embankment are shown on Plates 4 and 5. These sections are fairly consistent with the reportedly constructed slopes of 1V on 3H (upstream) and 1V on 2H (downstream) except the existing downstream slope appears somewhat flatter (approximately 1V on 2.25H). The crown width of the dam is 20 feet.

The upstream embankment slope of the dam is protected with riprap and appears to be in relatively good condition. The riprap extends to the crown in some areas while in other areas the degree of protection does not appear to be quite as uniform. Some wavewash and erosion was noted along the upstream face (see Photo 3), but these instances appeared to be minor.

The downstream embankment slope of the dam is overgrown with trees and bushes throughout the entire length of the dam (see Photo 4). Erosion gullies caused by apparent through seepage were observed on the downstream slope at stations 5+45 and 6+45 (see Photos 5 and 6) at locations approximately 15 to 20 feet down from the top of the dam. Estimated seepage flow was less than .5 gpm. It did not appear that any embankment material was being piped by the seepage flow. A sloughed area was also noted at Station 5+55 at a point approximately 15 feet down from the top of the dam. The area was approximately 5 feet long and had a 1 foot face. The embankment soil in the area was wet indicating that the sloughing may have been the result of through seepage. Other instances of through seepage were found to occur intermittently along the downstream slopes. Cattails and willows were also observed on the downstream slope.

The area at the downstream toe of the dam was soggy and spongy throughout most of the length of the dam. Cattails and other vegetation were observed in the area (see Photo 7). Some of the area contained as much as 6 inches of standing water. Although most of this appeared to be just trapped water from recent rains, seepage was observed at several areas near the toe (see Photos 8 and 9) just west of the primary discharge structure. Seepage quantities were indeterminable since it was difficult to differentiate between the seepage water and the standing water. It did not appear that any foundation material was being piped by the seepage flow.

d. Appurtenant Structures. A vertical drop inlet constructed of 8.3 feet of 36-inch diameter corrugated metal pipe (CMP) junctioned with 105 feet of 36-inch diameter CMP running horizontally through the embankment serves as the primary discharge (see Photos 10 and 11). A screw-type sliding gate located at the bend of the drop inlet is used to drawdown the water level for biological maintenance of the lake. The sliding gate could not be inspected because of the inaccessible location. The drop inlet and the discharge pipe appear to be in relatively good condition. The concrete apron at the downstream end of the discharge pipe, however, is in the process of being undermined (see Photo 12).

An emergency spillway located in the left abutment consists of a 125-foot long rectangular concrete channel with an average bottom width of 14 feet (see Photos 13 and 14). The concrete in the spillway appears to be in good condition. The downstream end of the emergency spillway, however, is in the process of being undermined (see Photo 15).

e. Reservoir Area. No wave wash, excessive erosion or slides were observed along the shore of the reservoir.

f. Downstream Channel. Some trees and brush were observed in the downstream channel.

3.2 EVALUATION

The conditions of observed through and underseepage could indicate a possible serious potential for failure of the embankment. These conditions need to be evaluated on a high priority basis in conjunction with seepage and stability analyses. Also, the continued growth of trees and brush on the downstream slope and the progressive undermining at the discharge structures are deficiencies which if left uncontrolled or uncorrected could lead to the development of potential problems.

SECTION 4 - OPERATION

4.1 PROCEDURES

The primary discharge system and the emergency spillway are uncontrolled; therefore, no regulating procedures exist for these structures. The screw-type sliding gate described in paragraph 3.1 d is used for biological lake maintenance.

4.2 MAINTENANCE OF DAM

Little maintenance has been done as shown by the growth of trees and bushes on the downstream slope and the undermining occurring at the downstream ends of the primary and emergency discharge structures.

4.3 MAINTENANCE OF OPERATING FACILITIES

No information is available concerning maintenance of the screw-type sliding gate.

4.4 DESCRIPTION OF ANY WARNING SYSTEMS IN EFFECT

The inspection team is not aware of any existing warning system for this dam.

4.5 EVALUATION

If the trees and brush growth on the downstream slope and the progressive undermining at the downstream ends of the primary and emergency discharge systems are allowed to continue, potential problems could develop.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. No design data are available.

b. Experience Data. The drainage area and lake surface area was developed using USGS Marquand, Missouri Quadrangle. The spillway and dam layout are from surveys made during the inspection.

c. Visual Observations.

(1) The vertical drop inlet and the emergency spillway appear to be in good condition.

(2) There is no trash rack for the vertical drop inlet.

(3) The vertical drop inlet is located approximately 150 feet from the left abutment while the spillway is located in the left abutment.

(4) Some undermining has occurred at the extreme downstream ends of the primary and emergency discharge structures.

(5) The screw-type sliding gate could not be inspected because of the inaccessible location.

d. Overtopping Potential. The spillway will pass 30 percent of the Probable Maximum Flood (PMF) at a discharge of 480 cfs without overtopping. The Probable Maximum Flood is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The PMF will overtop the embankment for a period of 6 hours at a depth of 1.8 feet at a discharge of 5100 cfs. The one-half PMF will also overtop the embankment for a period of 4 hours at a depth of 1.0 feet at a discharge of 2000 cfs. The 100-year frequency flood will not overtop the embankment. For its size and hazard category, this dam is required by the guidelines to pass from one-half PMF to PMF. However, considering the high hazard potential to life and property of 2 families downstream of the dam, the PMF is considered the appropriate spillway design flood. Because the spillway will not pass one-half PMF without overtopping but will pass the 10-year frequency flood, the dam is classified as "unsafe non-emergency." The data utilized in the preparation of the estimates were various Federal reports, data from field inspection and survey, and output from COE program, HEC-1, Dam Safety Version.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of the dam and appurtenant structures are discussed and evaluated in SECTIONS 3 and 5. The observed seepage occurring on the downstream slope and toe raise considerable concern for the continued stability of this dam. The conditions observed indicate that the stability safety factor of the downstream slope may be low when compared to the suggested safety factors presented in the "Recommended Guidelines for Safety Inspection of Dams," and that a potential for internal piping of embankment and foundation material exists.

b. Design and Construction Data. The design and construction data were limited to that information discussed in SECTION 2.

c. Operation Records. No operational records exist other than those observations made on this inspection.

d. Post Construction Changes. No post construction changes exist which will affect the structural stability of the dam.

e. Seismic Stability. This dam is located in Seismic Zone 2. However, it is located very near the boundary between Seismic Zones 2 and 3. Since this dam is located in Seismic Zone 2 and the proximity of Seismic Zone 3, it is possible that an earthquake could occur of sufficient intensity to cause severe damage or failure of the dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. Several items were noted during the visual inspection which should be corrected or controlled. These items are minor wavewash on the upstream embankment face; trees and brush on the downstream slope; erosion gullies and sloughing on the downstream slope; undermining at the downstream ends of both the primary and emergency discharge structures; trapped surface drainage water at the downstream toe of the dam; and observed seepage on the downstream embankment slope and toe. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record. Also these analyses should be utilized to detail the corrective actions called for in paragraph 7.2. The Probable Maximum Flood (the spillway design flood) and one-half of the Probable Maximum Flood will both overtop the dam. Because the spillway will not pass one-half of the PMF without overtopping, but will pass the 10-year frequency flood, the dam is classified as "unsafe non-emergency".

b. Adequacy of Information. Due to the lack of engineering design and construction data, the conclusions in this report were based on performance history and external visual conditions. The inspection team considers that these data are sufficient to support the conclusions herein.

c. Urgency. The remedial measures recommended in paragraph 7.2c should be accomplished in the near future. The stability and seepage analyses should be given priority by the owner and accomplished without delay in order to determine if corrective measures are necessary. The items recommended in paragraphs 7.2a and 7.2b should be pursued on a high-priority basis. If the safety deficiencies listed in paragraph 7.1a are not corrected in a timely manner, they could lead to the development of potential problems.

d. Necessity for Phase II. Based on the results of the Phase I inspection, no Phase II inspection is recommended.

e. Seismic Stability. This dam is located in Seismic Zone 2. However, it is located very near the boundary between Seismic Zones 2 and 3. Since this dam is located in Seismic Zone 2 and the proximity of Seismic Zone 3, it is possible that an earthquake could occur of sufficient intensity to cause severe damage or failure of the dam.

7.2 REMEDIAL MEASURES

a. Alternatives. Spillway size and/or height of dam should be increased to pass the Probable Maximum Flood without overtopping the dam.

b. Perform seepage and stability analyses to assess the safety concerns raised by the seepage present on the downstream slope and toe of the dam. Use the results of these analyses to design appropriate corrective measures.

c. O & M Maintenance and Procedures. The following O & M maintenance and procedures are recommended:

(1) Repair the wavewash areas on the upstream embankment.

(2) Remove trees and bushes on the downstream embankment. Care should be taken during removal not to destroy the existing conditions of the embankment.

(3) Repair the downstream embankment where gullies and sloughing have occurred.

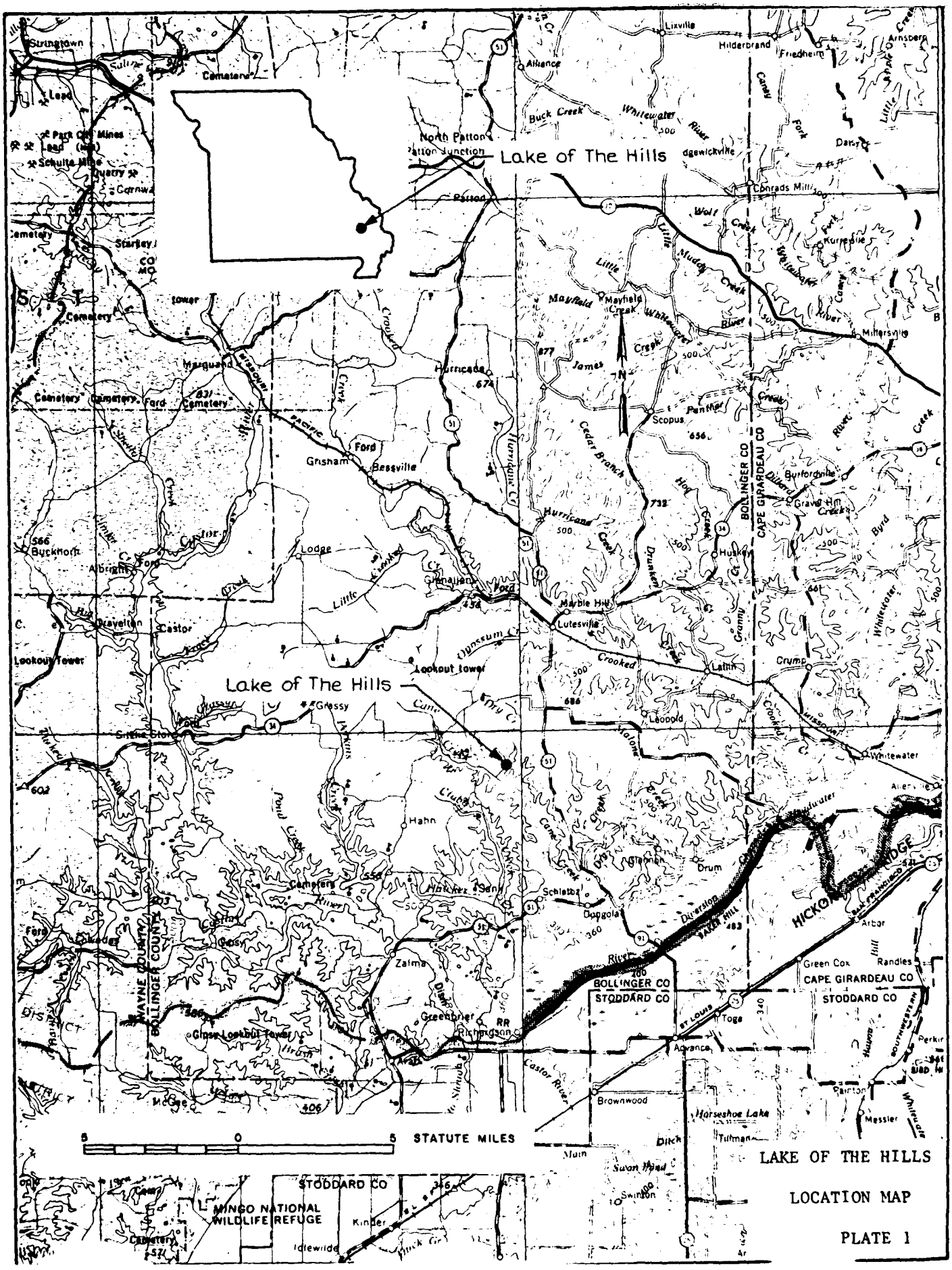
(4) Install a trash rack at the vertical drop inlet to prevent the discharge pipe from becoming obstructed.

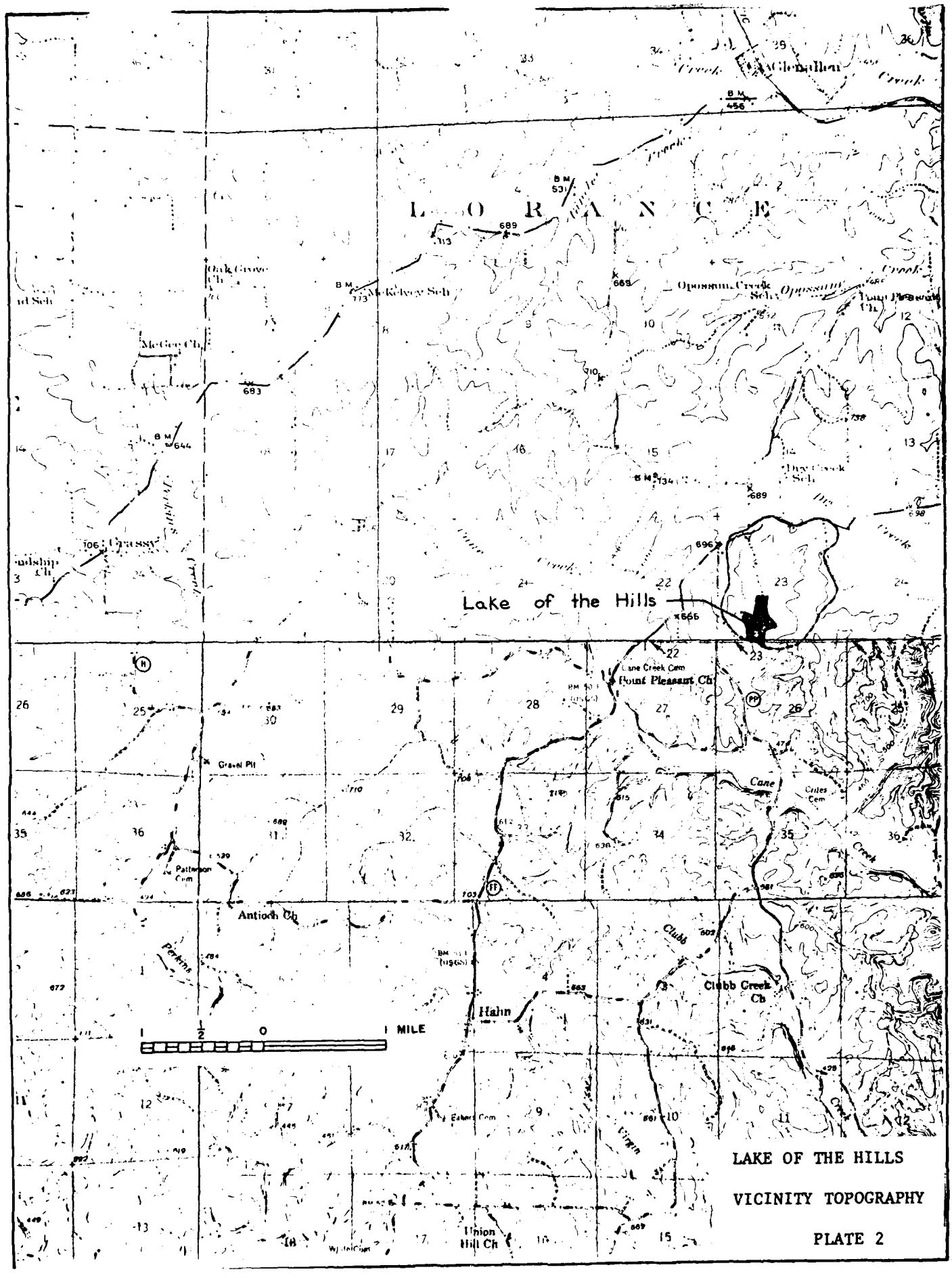
(5) Enlarge and/or extend erosion protection works under the downstream end of the discharge pipe of the vertical drop inlet and emergency spillway exit.

(6) Perform minor ditching or reshaping to drain water impounded on (or near) downstream toe of dam.

(7) The downstream slope and toe should be closely monitored for seepage and erosion. If seepage quantities and/or erosion observed during monitoring indicate increases or signs of material being piped from the embankment, immediate action shall be taken to rectify these conditions.

(8) A detailed inspection of the dam should be made at least every 5 years by an engineer experienced in design and construction of dams.

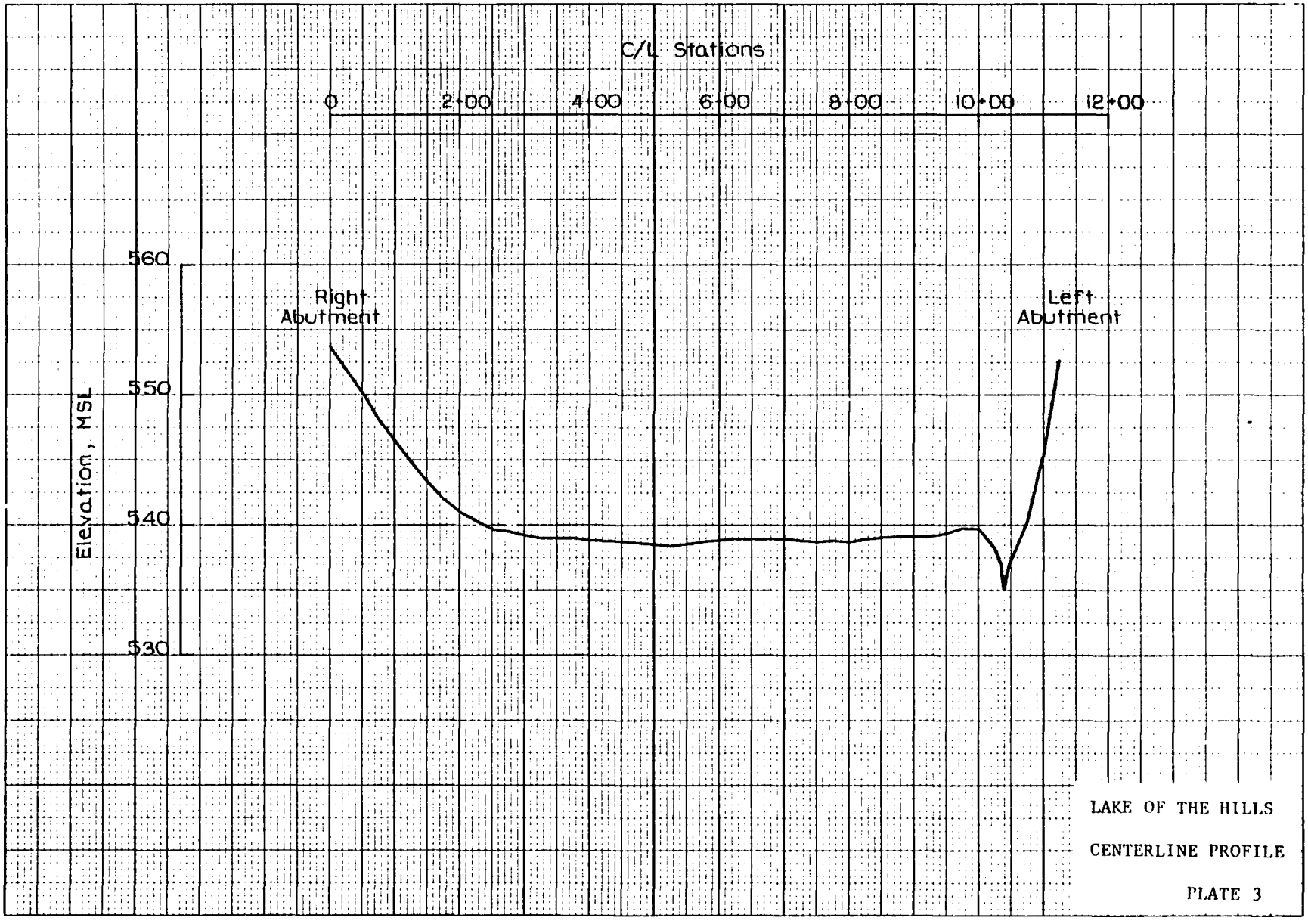

Lake of The Hills
Lake of The Hills
5 0 5 STATUTE MILES
LAKE OF THE HILLS
LOCATION MAP
PLATE 1



LAKE OF THE HILLS

VICINITY TOPOGRAPHY

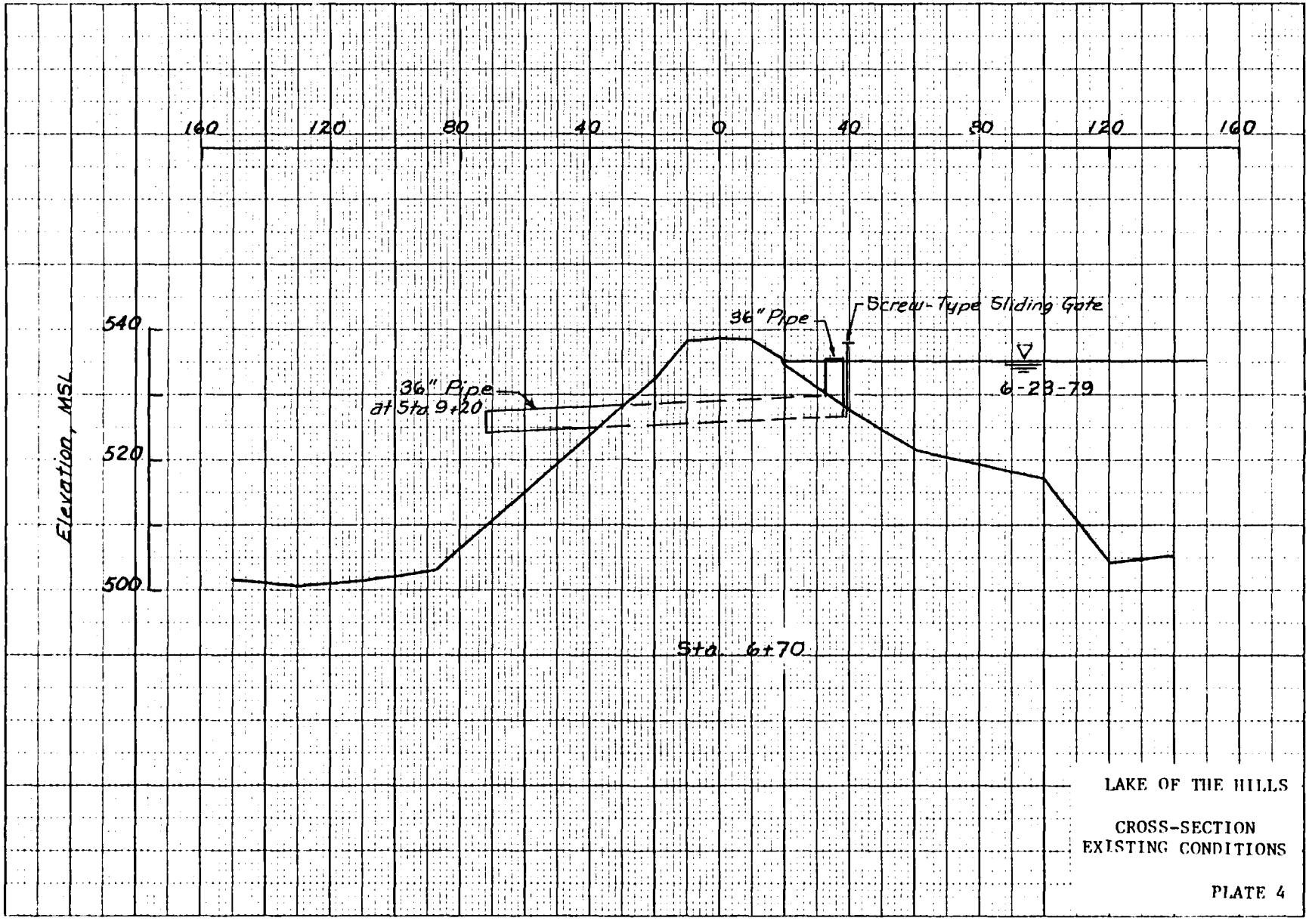
PLATE 2



LAKE OF THE HILLS

CENTERLINE PROFILE

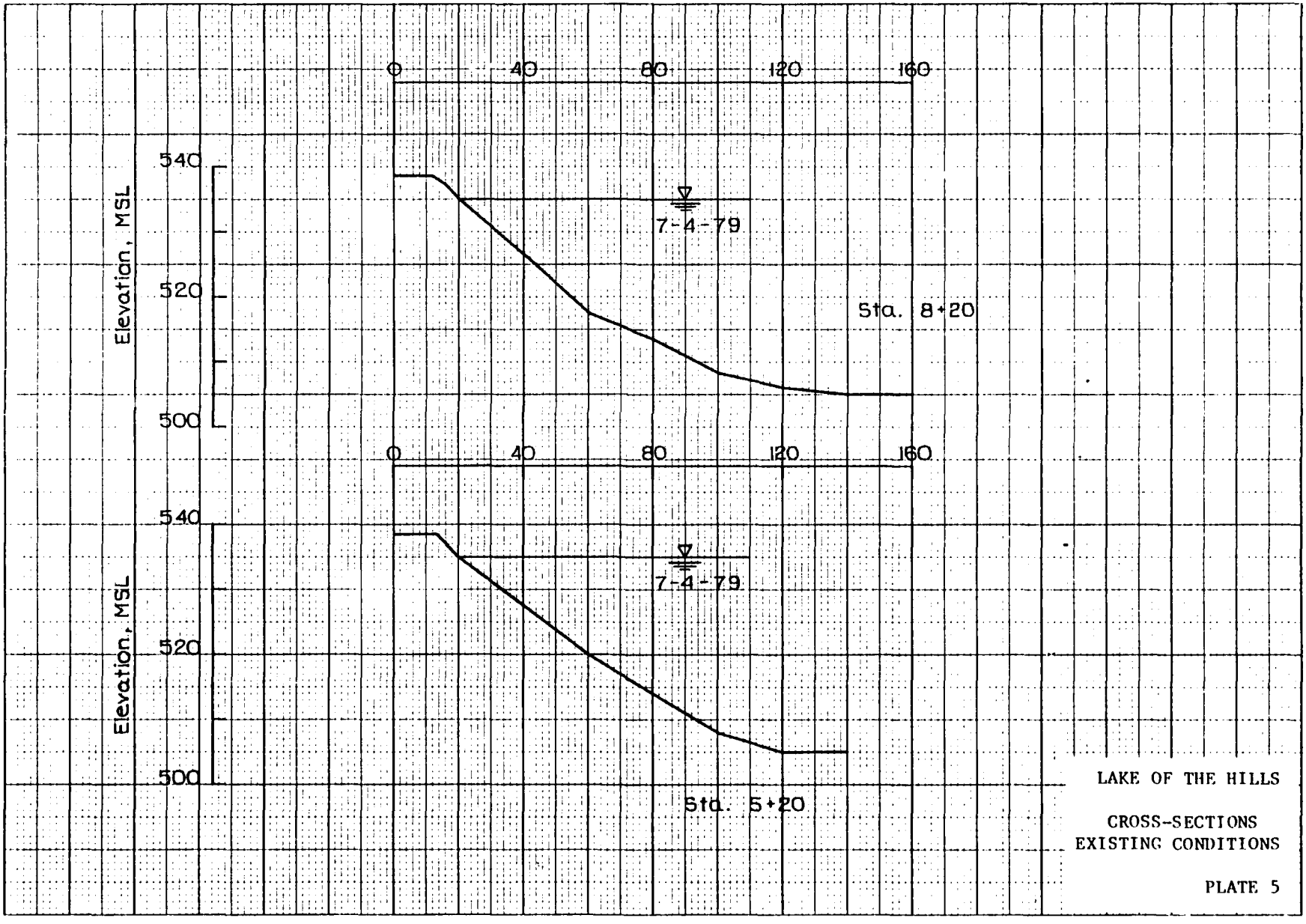
PLATE 3



LAKE OF THE HILLS

CROSS-SECTION
EXISTING CONDITIONS

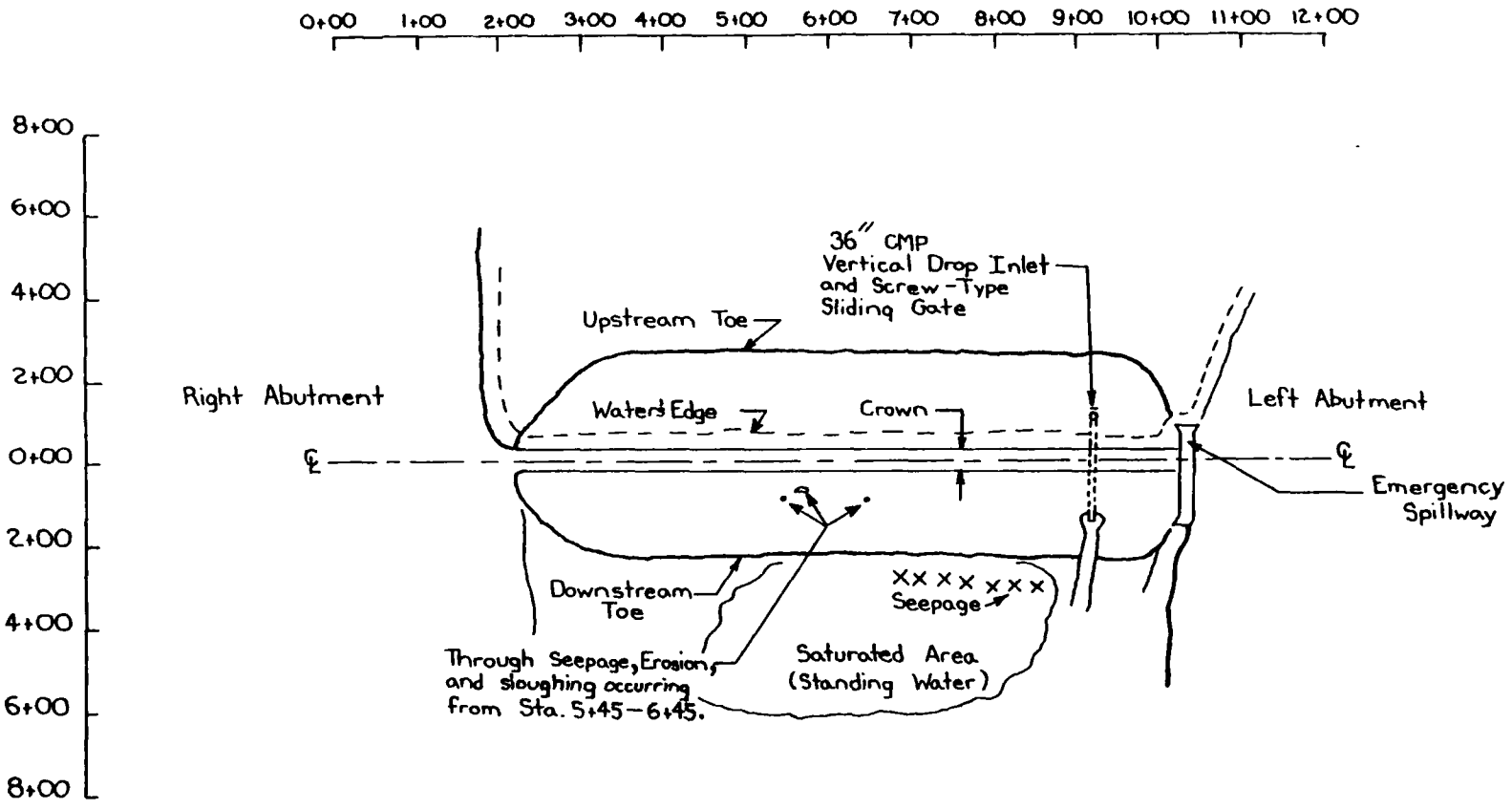
PLATE 4



LAKE OF THE HILLS

CROSS-SECTIONS
EXISTING CONDITIONS

PLATE 5



LAKE OF THE HILLS

DAM PLAN VIEW

PLATE 6

APPENDIX A
HYDROLOGY AND HYDRAULIC

1. Narrative. The methods and sources of data were primarily those suggested by the Hydraulics Branch, St. Louis District, Corps of Engineers. Specific references and methods will be discussed below. A field inspection and survey was made to determine the outlet structures and the topographic characteristics of the dam. HEC-1, Dam Safety Version was used in conjunction with appropriate input parameters to compute inflow hydrographs, determine storage, and route through the structure.

a. Rainfall. The PMF was developed using Hydrometeorological Report No. 33. The "Hop Brook" reduction factor was not used to adjust the rainfall for this study. The distribution of rainfall was developed using the criteria as described by EM 1110-2-1411 (Standard Project Storm).

PMF Rainfall	26.9 in.	
PMF Percentages	6 hr.	102
	12 hr.	120
	24 hr.	130
	48 hr.	140

b. Unit Hydrograph Coefficients. The unit hydrograph for the drainage basin was developed using the Snyder Method as outlined in HEC-1, Dam Safety Version. Two methods of determining time of concentration were used, namely the Snyder's Method and Kirpich Method. The variable used for the appropriate method are listed below:

Snyder's: $t_p = C_t(L\,L_{cg})^{0.3}$; L and L_{cg} in miles

L = 6458 feet = 1.22 miles

L_{cg} = 2604 feet = 0.49 miles

Stream Slope = 97 ft/mile = .018 ft/ft

C_t = .58

t_p = .50 hr.

t_c = .64 hr.

Kirpich $t_c = .00013 \left(\frac{L \text{ ft}}{\sqrt{\text{Slope, ft/ft}}} \right)^{.77}$

t_c = .52 hr.

Where L = length of the main stream channel from the outlet to the divide

L_{CG} = length along the main channel to a point opposite the watershed centroid

C_t = coefficient used in Snyder's Method

t_p = time to peak (hours)

t_c = time of concentration (hours)

Consequently, since the time of concentrations agreed so closely, a value for the t_p was chosen to be .50 hour or 30 minutes which necessitated developing a 10-minute unit hydrograph and applying only a 48 hour rainfall to develop the inflow hydrographs.

The general soils map of Bollinger County indicates that Lake of the Hills Dam lies in an area where the soil is of the Clarksville, Fullerton, Lebanon Association. This places the area primarily in a Soil Broup B. The primary soil cover consists of woods in a fair hydrologic condition which gives a value of CN of 78 for antecedent moisture condition III. Consequently, a value of C_p = .657 was chosen as the runoff parameter to be used in Snyder's Method. Listed below are the remaining parameters necessary to develop the unit hydrograph of 10-minute duration.

C_p = .657
Drainage Area = .7688 sq. mi.

The unit hydrograph ordinates are found in the computer printout.

b. Loss Rates. A loss rate of .5 in. initially and .05 in./hr. was chosen based upon engineering experience.

c. Base Flow and Antecedent Flood Conditions. A base flow of 1 cfs was selected and the routing was started at the low point in the spillway crest of 535.1 m.s.l.

d. Hydrograph Routing. The routing of the inflow through the dam was a combination of the computed outflow rating curve for the outfall structures and the non-level routing option of HEC-1, Dam Safety Version. Single step routing using the "Modified Puls" Method was used to actually route the flow through the embankment. The rating for the outlet structure was developed to consider two cases: (1) weir flow from elevation 535.1 feet m.s.l. to elevation 537.1 feet m.s.l. (2) pipe-full conditions from elevation 537.1 feet m.s.l. to elevation 542.0 feet m.s.l. The flow through the emergency spillway was calculated using the broad-crested weir equation for a rectangular concrete channel. Listed below are the assumptions used to perform the calculation.

(1) Drop Inlet Structure

(a) Weir flow: Elevation 535.1 to 537.1 feet m.s.l.

$$Q = C\ P\ H^{3/2}$$

$C = 3.1$

$P = 3\pi = 9.42$ feet

H = Head above elevation 535.1

(b) Pipe-full conditions

Vertical Drop Inlet	Horizontal Pipe
D = 36 inch CMP	D = 36 inch CMP
L = 8.3 feet	L = 105 feet
n = .024	n = .024

head losses: $h_{ent} = 1/2\ \frac{V^2}{2g}$

$$h_{bend} = \frac{V^2}{2g}$$

$$h_{exit} = \frac{V^2}{2g}$$

h_f = friction loss (Manning's Equation)

$$H = 2.5\frac{V^2}{2g} + h_f$$

(2) Emergency Spillway

$Q = C\ A\ H^{1/2}$
$C = 3.1$
A = Area
H = Head above emergency spillway crest

The combined output rating curve can be found on the Y4 and Y5 curves of the computer input. The invert elevation from which to calculate the H, Head, values for the pipe-full condition is 526.0 feet m.s.l.

e. Storage. The storage was calculated by HEC-1, Dam Safety Version using as input the surface areas and respective elevations as determined from the Marquand, Missouri USGS Quadrangle.

```
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
*****************************
  1                A
  2                A                                  NON-FEDERAL DAM INSPECTION
  3                A                                        DAM #30077
  4                A                                  LAKE OF THE HILLS DAM
  5                R     300       0      10      -0      -0      -0      -0      -0      -0      -0
  6                1       5
  7                J       1       9       1
  8                J1     .1      .2      .3      .4      .45     .48     .49      .5      1.
  9                K       0       1                                       1
 10                1                                PROBABLE MAXIMUM PRECIPITATION-48 HR DURATION
 11                M       1       1    .7488              .7488      1.
 12                P              26.9     102      120      130      100
 13                1                                                          .5      .05
 14                W      .5    .657
 15                X       1       1       2
 16                K       1       2                                       1
 17                K1                       ROUTED FLOWS THROUGH LAKE OF THE HILLS DAM
 18                Y                                1       1
 19                Y1      1                                        -535.1      -1
 20                YQ  535.1   535.8   536.5   537.10   538.0   538.5   539.0   540.0   541.0   542.0
 21                YS      0   42.53  120.29  208.60   299.78  359.26  423.16  562.99  717.46  885.28
 22                $A      0  30.798  75.969 110.870
 23                $E    500     520     580     560
 24                $$  535.1
 25                $D  538.7
 26                $L      0      21      29     869      619     771     796     811     961
 27                $V  537.1   538.2   538.7   539.0    539.0   539.8   539.8   500.0   505.0
 28                K      99
```

PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

MIDDLE HYDROGRAPH AT

```
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********

RUN  DATE: 20 AUG 79
     TIME: 09.03.11
```

NON-FEDERAL DAM INSPECTION
DAM #30077
LAKE OF THE HILLS DAM

JOB SPECIFICATION

NO	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
300	0	10	-0	-0	-0	-0	-0	-0	-0
			JOPER	NWT	LROPT	TRACE			
			5	-0	-0	-0			

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 9 LRTIO= 1
RTIOS= .10 .20 .30 .40 .45 .48 .49 .50 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

PROBABLE MAXIMUM PRECIPITATION-48 HR DURATION

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	-0	-0	-0	-0	1	-0	-0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	1	.77	-0.	.77	1.00	-0.	-0	-0	-0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
-0.	26.90	102.00	120.00	130.00	140.00	-0.	-0.

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
-0	-0.	-0.	1.00	-0.	-0.	1.00	.50	.05	-0.	-0.

UNIT HYDROGRAPH DATA
TP= .50 CP= .66 NTA= -0

RECESSION DATA
STRTQ= 1.00 QRCSN= 1.00 RTIOR= 2.00
APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC= 3.82 AND R= 2.17 INTERVALS

UNIT HYDROGRAPH 10 END-OF-PERIOD ORDINATES, LAG= .50 HOURS, CP= .66 VOL= 1.00

106.	568.	601.	635.	475.	297.	186.	117.	73.	46.
29.	18.	11.	7.						

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.10	1	.00	0.	.00	1.	1.02	1.10	151	.03	.02	.01	57.
1.01	.20	2	.00	0.	.00	1.	1.02	1.20	152	.03	.02	.01	60.
1.01	.30	3	.00	0.	.00	1.	1.02	1.30	153	.03	.02	.01	62.
1.01	.40	4	.00	0.	.00	1.	1.02	1.40	154	.04	.02	.01	62.
1.01	.50	5	.00	0.	.00	1.	1.02	1.50	155	.03	.02	.01	63.
1.01	1.00	6	.00	0.	.00	1.	1.02	2.00	156	.04	.02	.01	64.
1.01	1.10	7	.00	0.	.00								

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS								
				RATIO 1 .10	RATIO 2 .20	RATIO 3 .30	RATIO 4 .40	RATIO 5 .45	RATIO 6 .88	RATIO 7 .99	RATIO 8 .50	RATIO 9 1.00
HYDROGRAPH AT	1	.77	1	566.	1132.	1698.	2264.	2547.	2717.	2776.	2831.	5661.
	(	1.99)	(	16.03)(	32.06)(	48.09)(	64.12)(	72.14)(	76.95)(	78.55)(	80.15)(	160.30)
ROUTED TO	2	.77	1	125.	279.	479.	1183.	1583.	1868.	1958.	2037.	5118.
	(	1.99)	(	3.55)(	7.91)(	13.57)(	32.36)(	48.88)(	52.90)(	55.34)(	57.68)(	144.92)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	535.10	535.10	538.70
STORAGE	899.	899.	1143.
OUTFLOW	0.	0.	858.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	536.53	0.	992.	125.	0.	42.33	0.
.20	537.73	0.	1078.	279.	0.	42.17	0.
.30	538.78	.08	1149.	479.	1.50	41.83	0.
.40	539.31	.61	1188.	1143.	3.17	40.83	0.
.45	539.49	.79	1202.	1583.	3.50	40.50	0.
.48	539.60	.90	1209.	1868.	3.50	40.50	0.
.49	539.63	.93	1211.	1954.	3.67	40.50	0.
.50	539.66	.96	1214.	2037.	3.67	40.50	0.
1.00	540.85	1.75	1274.	5118.	6.17	40.33	0.

PHOTO 1: Overview of Lake and Dam

PHOTO 2: Crest of Dam

PHOTO 3: Minor Wavewash on Upstream Slope

PHOTO 4: Downstream Embankment Slope

PHOTO 5: Seepage on Downstream Slope

PHOTO 6: Seepage on Downstream Slope

PHOTO 7: Downstream Embankment Toe

PHOTO 8: Seepage at Downstream Toe

PHOTO 9: Seepage at Downstream Toe

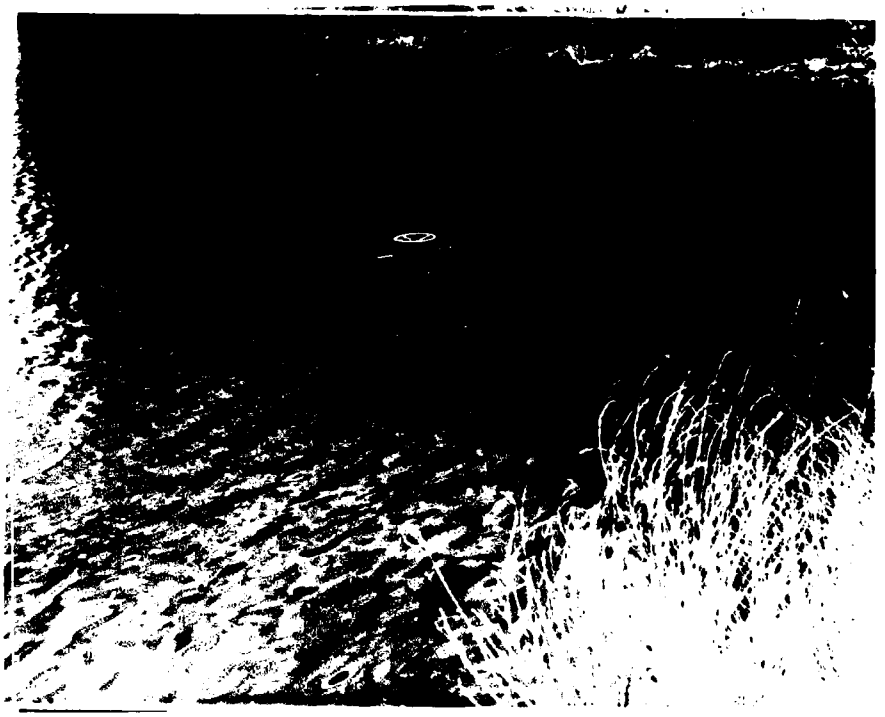


PHOTO 10: Inlet of Vertical Structure

PHOTO 11: Discharge of Vertical Structure

PHOTO 12: Discharge Area of Vertical Structure

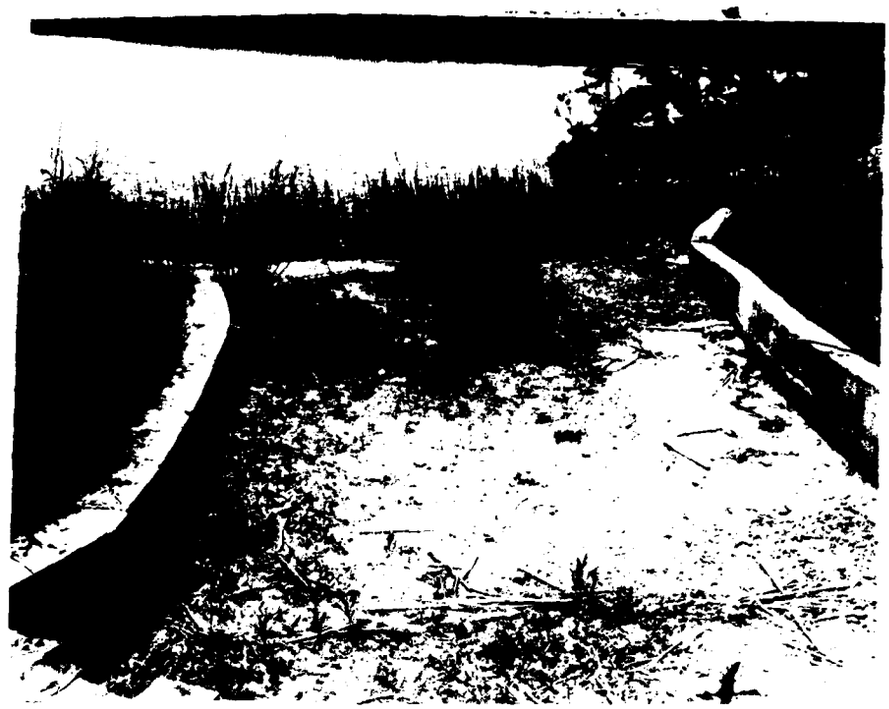
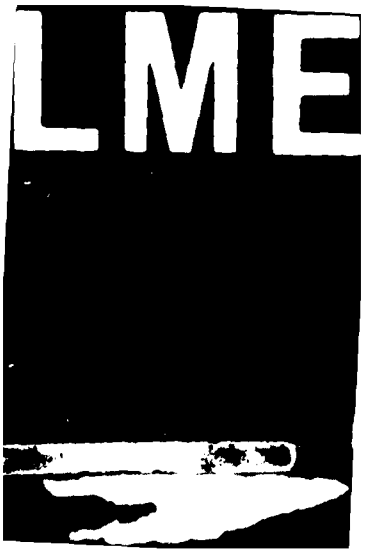


PHOTO 13: Emergency Spillway - Upstream View

PHOTO 14: Emergency Spillway - Downstream View

PHOTO 15: Area Downstream of Emergency Spillway

PHOTO 16: Typical Dwelling Downstream of Dam


LME